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Edwards Street Laboratory
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New Haven, Connecticut

Mine Detection and Location with Type 1174 Sonar

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Technical Report No. 25
(ESL:423:Serial 01)
2 March 1954

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SUMMARY

During the summer of 1953 preliminary tests were conducted in Narragansett Bay on a new sonar for mine detection and location, known as the Type 1174 Sonar. This sonar, designed for small-boat operation, used two independent echo-ranging systems at 67 and 100 kc, and included a facsimile recorder for permanently recording the echoes, in addition to cathode-ray oscilloscope presentation.

Early operations included ranging on small targets such as triplanes, suspended at various depths, while equipment parameters were studied in order to obtain a satisfactory working combination. An adequate test of the 67-kc unit was not made because of the restricted beam width available and the fixed azimuth of its transducer.

Tests included ranging on bottom mines and spheres, the approximate locations of which were known from observed splash positions. The sonar boat was directed to these locations and through appropriate search patterns by a radar operator on shore; this system of radar-guided navigation was found very successful. For 158 sonar contacts, the position of the boat was recorded by surveyors on shore, and from the plotted boat positions vectors were drawn to the target from the sonar range and bearing data. These 158 contacts are analyzed in this report and compared with the best known positions of objects on the bottom, from splash positions or recovery points. Approximately 14% of the contacts

lie within 50 feet of known underwater objects. Discrepancies between observed and known positions are thought to be due to the existence of unknown objects and to other factors not inherent in the sonar itself, such as errors in reconstructing the boat position at the contact.

Mine detection with a small-boat sonar is practical, but its effectiveness depends on the use of a seaworthy vessel, precise navigation, and accurate location of the boat position at any instant.

1. Introduction

Mine countermeasures may be divided into four stages: detection, location, identification or classification, and inactivation or destruction of the mine. Echo-ranging by means of underwater sound is one of the few effective techniques for detecting and locating submerged mines. Mine-detection sonars have been under development for some time, culminating in the adoption by the Navy of the AN/UQS-1 for minesweepers and other vessels.

In 1952 the Edwards Street Laboratory recommended study of a mine-detection sonar for small boat installation, emphasizing simplicity of design and operation, compactness, ruggedness, and provision of a permanent record in addition to immediate presentation of information. Response to this suggestion led to the formation in the summer of 1952 of a field development group which assembled and operated a sonar system meeting these requirements in broad outline, in order to study the feasibility of such a sonar in mine detection and location.

To save time and expense, this sonar was assembled for the most part from currently available laboratory instruments. A Hewlett-Packard Model 200C audio oscillator, a pulse modulator of USN/USL design, and a McIntosh 50W2 power amplifier comprised the transmitter, while a wide-band amplifier, a band-pass filter, a Tektronix Model 512 oscilloscope, and a Hogan Model FR-8 facsimile recorder made up the receiver. Two identical barium titanate line hydrophones, masked to minimize direct pickup and to achieve the desired directivity pattern, were used as transmitting and receiving elements at their resonant frequency of 67 kc, and were mounted on a manually rotated shaft over the starboard side of a 42'6" torpedo retriever.

Tests with this system included ranging on fixed buoyed targets of known characteristics, triplanes, and air-dropped bottom mines (Marks 25 and 36). These tests were sufficiently encouraging to justify the design and construction of a mine-detection sonar, meeting more specifically the requirements outlined above. The development of this sonar by Melpar, Inc., under subcontract with Yale University, was begun in the fall of 1952, and the complete sonar, known as Type 1174, was delivered to the Beavertail Laboratory in the spring of 1953 and tested in Narragansett Bay that summer. This report describes those tests.

It is a pleasure for the authors to acknowledge the guidance and counsel of H.A. Fairbank, who initiated this program and to whom is due in large part such success as it may have achieved. Credit is also due to T.W. Morris, who contributed substantially to planning and carrying out the tests.

2. Equipment

2.1 Description of the Type 1174 Sonar.

The Type 1174 Sonar consists of two separate units: one at 67 kc at a fixed bearing (090 relative), designed for initial contacts as the boat follows its search pattern, and the other at 100 kc, trainable from 000 to 180 relative, for following the target with a narrower beam and locating it more accurately. Each receiving circuit was designed to be connected to either a linear (A-scope) cathode ray oscilloscope or to a facsimile recorder, or to both when the other receiving circuit was not used; the two sonars could also be operated simultaneously, one connected to the A-scope and the other to the recorder. Each unit operates with either a 400-foot or an 800-foot range scale, and each receiver has time-varied gain (TVG) for optimum adjustment of the reverberation level. Figure 1 shows the equipment, with an auxiliary oscilloscope and vacuum-tube voltmeter, and Figure 3 is a view of the cabin extension of the torpedo retriever in which the equipment was mounted.

The 100-kc unit was designed to be as versatile, electrically and mechanically, as was conveniently possible. The relative bearing of the transducer is variable from 000 to 180, and the tilt angle, or depression of the beam, from 15° above the horizontal to 15° below; the horizontal beam width could be fixed at 2°, 4°, or 8° (-10 db), and the pulse length at

0.25, 0.5, or 1.0 ms. Only the pulse length could be varied in the 67-kc unit.

The total power input to the system, supplied by a 110-volt 1200-watt Kato gasoline-engine motor generator through a Sola voltage regulator, was 680 volt-amperes, while the peak pulse power output into a resistive load was of the order of 1 kw for each unit.

The transducers are two line hydrophones composed of arrays of barium titanate cylinders, each acting as transmitter and receiver at its own resonant frequency; the 67-kc transducer was an SKH-3 unit of the type used in 1952, and the 100-kc transducer was constructed so as to operate 1, 2, or 4 sections of the 4-cylinder array in order to vary the beam width. Both transducers were mounted at the end of a vertical steel column, as illustrated in Figure 2 and could be lowered to a depth of about 6 feet by means of a hand-operated winch on the deck. The assembly is shown in Figure 4, and the directivity patterns in Figures 5 through 8. Table I summarizes the specifications of the Type 1174 Sonar and compares them with other current sonars.

2.2 Modifications.

Several modifications were made in the equipment with a view to improving operating efficiency. The three-speed motor which trained the 100-kc transducer was found to have too high

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Table I

Sonar		Type 1174		AN/UQS-1	XHB	Sea Scanar
Frequency	kc	67	100	100	42-36 (FM)	270
Pulse length	ms	0.25-1.0	0.25-1.0	1	5-0.3	1 (0.5-4.0)
Peak power	kw	1	1	10		0.2
Range scales	ft	400,800	400,800	600,1500,3000	300-4800	400,800,1600
Beam width (horizontal)		4° (-10 db)	2°-8° (-10 db)	2.5° (60°*)	3° (360°*)	5.7° (-3 db)
Beam width (vertical)		36° (-3 db)	80° (-3 db)	10°	20° (30°*)	5.7° (-3 db)
Depression (vertical)		Fixed	15° to -15°	5° to -50°	-	$+2^\circ$ to -90°
Scan speed	$^\circ$/s	0	5	12-40	18	4.5-18
Visual presentation		5" A-scope, facsimile recorder		10" PPI	7" PPI Geographic plot	7" PPI, 3" A-scope
Aural presentation		No	No	No	Yes	Yes
Number of channels		1	1	1	300	1
Total weight	lbs	1057		9860 (3860**)	1600	212
Equipment size	ft^3	17.2				3.2
Maximum power consumption	kw	0.7		7.2		0.3

* Sector width
** Reported modification

a scanning rate at its lowest speed, and was replaced by a slower, single-speed motor to permit the target to be retained in view longer during search operations and to facilitate sweeping slowly across the target. An additional rapid sweep for changing the sector of observation would be very desirable.

Various minor mechanical difficulties were encountered in lowering the transducers and particularly in the operation of the facsimile recorder, a commercial unit which had been incorporated in the Type 1174 Sonar. The only circuit change was a minor one, enabling the 100-kc echo to be presented on the recorder without operating the 67-kc transmitter.

2.3 Power Measurements.

Acoustic power output measurements of the Type 1174 Sonar were made using an OCP-3 test and calibrating set, with the calibrating hydrophone suspended at distances of 3 and 10 feet from the transducers. Because the OCP-3 is designed to monitor a continuous signal level instead of pulses, it was necessary to use an auxiliary oscilloscope, which was calibrated with a 1-db signal from the OCP-3 oscillator impressed upon its deflection plates; the relative intensities in db referred to 1 dyne/cm^2 received by the calibrating hydrophone were then read off directly from the oscilloscope. The transmitting levels were about 90 db at 100 kc and 80 db at 67 kc at a distance of 10 feet.

Observations made when the transmitter was disconnected from the transducer confirmed that signal discrimination was reverberation limited under all conditions of operation; the general level of noise from the circuit elements was negligible.

3. Operations

3.1 Triplanes.

3.11 Purpose of the triplane targets.

A period of general testing was undertaken in June and July 1953 before sphere and mine operations were attempted. It was thought desirable to determine (1) the optimum instrument parameters for general use of the equipment; (2) the sensitivity and reliability of the equipment in detecting underwater targets; (3) possible echoes from surface targets; and (4) the effect of bottom conditions on reverberation levels and signal discrimination.

The target used in these tests was a 14-inch aluminum triplane, illustrated in Figure 9. The target strength of a triplane of length ℓ for sound of wave length λ is equal to that of a sphere of radius $r = 2.17\ell^2/\lambda$; thus a 14-inch triplane has a theoretical target strength at 100 kc of 20 db, equal to that of a sphere of radius 60 ft. Figure 10 shows a typical triplane echo observed on the A-scope.

The triplane was used under a number of different conditions during these preliminary trials: at depths from 10 to 100 feet, at ranges up to 500 feet, in various thermal gradients and sea states (up to sea state 3). It was either towed by a small rowboat while the retriever was docked, or suspended from a buoy while the retriever was maneuvered about it; the latter operation was more often used, since the conditions approximated those encountered in practice.

Other tests with triplane targets were made at the dock, in order to determine the limiting angles of view for the target; at ranges up to 300 feet, the angle of view did not exceed 5° for 0.25-ms pulses at 100 kc with a beam width of 8°. The difficulties later encountered in retaining small targets in view with the equipment were already foreseen during these early tests.

One of the two triplanes was faced with 1/8-inch thick Celltite neoprene to study the effect of a change in acoustic coupling between the water and the triplane surface. No quantitative information was obtained, but observations with the A-scope and the recorder failed to reveal any apparent difference in the echoes from the treated and untreated triplanes.

3.12 Buoy echoes.

Suspending the triplane from a cylindrical can buoy approximately 2.5 feet long and 0.5 foot in diameter introduced the possibility of echoes from the buoy interfering with echoes from the triplane. Buoy echoes were indeed observed in the absence of the triplane, but only at ranges of less than 200 feet, usually only within 50 to 100 feet. On several occasions when the triplane was suspended from the can buoy, multiple echo patterns were observed, presumably attributable to multiple surface reflections. Figure 11 is an example of these multiple echoes, while Figures 12 and 13 show typical echoes from the triplane and from the buoy alone respectively.

3.13 Thermal conditions.

Bathythermograph observations were made on several occasions in the area of operations with triplanes, but the small thermal gradients present, of the order of 0.1°F/ft, had little if any effect on the detection of the triplanes at ranges up to 500 feet.

3.14 Summary of triplane operations.

Nineteen of the twenty-five operations on buoyed or anchored triplanes were successful to some extent; on the other six, less satisfactory results were attributed to boat failures or unfavorable target positions. A typical facsimile record of one of these operations had identifiable echoes from the triplane at scattered positions totalling a length of 17 inches, while the entire record was 75 inches long; the paper progressed at a rate of 6 inch/min. on the 400 foot range. The triplane during this test was on the bottom in 60 feet of water. Not unexpectedly, a triplane on the bottom was more difficult to detect and to retain in the beam than one suspended off the bottom.

The results of the triplane operations suggested that it would be feasible with the Type 1174 Sonar to range on underwater targets of the size of mines, but it was apparent that the number of "looks" at a target under most conditions would be a limiting factor in its use.

3.15 Bottom reverberation.

A single continuous run was made in water varying in depth from 20 to 115 feet, with an NK-7 fathometer in addition to the sonar. The background at 100 kc was negligible at ranges between about 20 feet and the depth of the water, indicating only insignificant contributions from surface and volume reverberation during this run; the effect at 67 kc was much less, since the vertical beam is much narrower at 67 kc than at 100 kc (see Figures 5 and 6). Figure 16 shows facsimile records of parts of this run.

3.2 Sphere operations.

After the triplane tests, four hollow steel spheres, 38 inches in diameter, were laid on a smooth bottom in the West Passage of Narragansett Bay, in about 50 feet of water.

The positions of the spheres upon sinking below the surface were recorded by triangulation from two shore stations, and during two days of operations the spheres were used as sonar targets. Navigation of the retriever to the target positions was assisted by directions from a radar operator on shore; at each sonar contact, the range and bearing of the target relative to the boat, and the position of the boat with respect to the shore stations were recorded. The results of these and other plotted sonar contacts are presented in Section 5. Use of the spheres allowed a rough estimate of the target strength of a mine by comparing echoes from each.

3.3 Mine operations.

The rest of the summer was spent in attempting to detect and locate bottom mines, mostly Mark 25 and Mark 36 mines which had been dropped by air and were concentrated in an area about one mile square in the West Passage.

In these operations, the retriever was monitored by radar from the Beavertail Laboratory and directed by radio to the appropriate area. Locations of the known splash positions of the mines had been plotted on the PPI screen of the radar and after the retriever was brought to the general operating area, the radar operator would direct the boat by radio so that the retriever would pass the desired targets within the maximum range of the sonar. The boat would attempt to search the area, either in a rectangular pattern (east-west and northsouth) or in a circle around the known splash positions, but at the usual speed of several knots its actual course was considerably affected by the winds and currents.

During these operations, two observers at the sonar, one at the A-scope and the other at the facsimile recorder, and a radio operator were stationed on the retriever. At each contact, the operator at the A-scope gave the range and relative bearing of the target, the radio operator recorded these data as well as the heading of the boat from a simple compass, and transmitted a mark by radio. Surveyors were stationed at two shore stations on about half of the operating days, and recorded the position of the boat at each mark. On several occasions the surveyors were supplemented by photographers, who recorded and later reconstructed photographically the position of the boat at each mark; positions plotted from the surveyors' and from the photographers' data were in excellent agreement.

The radar operator at the Beavertail laboratory observed the position of the retriever at each mark, and when the range, bearing, and heading of the boat were relayed to him, he plotted the contact on the PPI screen. Thus he was able immediately to compare the contacts with the known splash points and to direct the retriever to the most appropriate course for locating the mines.

On occasional joint operations with other groups from the Beavertail Laboratory a buoy would be dropped to study the possibility of further search by sonar or by divers without radar assistance. Additional contacts could often be obtained by the sonar alone, which confirmed the contact on which the buoy was dropped; in the case of further search by divers, the results are inconclusive, although some spectacular discoveries were made of airplane wreckage and an old shipwreck.

4. Technical Results

4.1 General objectives.

Since evaluation of the Type 1174 Sonar in mine detection and location was a prime objective, as well as determination of the optimum operating parameters, decisions had to be made on the most satisfactory values of these parameters during the early operations. Time did not permit trials with each combination of the available frequencies, pulse lengths, repetition rates, beam widths, and tilt angles, but several apparently satisfactory combinations were adopted after relatively few tests.

Operations were considered satisfactory when at least a few echoes were being received during each run past the mines. The contact rate was found to depend on the length of time the boat had been searching; during the first hour of search the contacts were usually very few, but once these few had been made it was usually easy to follow a course which insured a higher rate of contact. Thus, the last half hour of search was usually much more fruitful than the first full hour; with 50% additional searching time (which need not have lengthened the working day) the number of contacts could have been doubled, with correspondingly more combinations of parameters tested. Unfortunately, the boat crew had to be returned to their base at specified hours, and travel time to the operating area frequently exceeded half an hour, so this additional time was not available.

In spite of the limited time available, satisfactory values of the parameters available in the present equipment were found. In general the equipment worked as designed, the only notable exceptions being in the training system, as described in Section 2, and in the facsimile recorder.

4.2 The facsimile recorder and the A-scope.

The value of the facsimile recorder lies in its ability to integrate successive echoes and to present a permanent record of all preceding signals and echoes. This is important because it provides an immediate confirmation of echoes seen on the A-scope, and reveals the existence of echoes which otherwise escape notice. The appearance of the facsimile record, when subsequently correlated with photographs of the corresponding A-scope record, could aid in discriminating, for example, between mines and other objects.

In spite of mechanical difficulties with the particular recorder, the usefulness of a facsimile recorder as an integral part of such a system was clearly demonstrated. The specific inadequacies present need not be discussed here, as they pertain only to the design of such an instrument.

The A-scope presentation was satisfactory, although the occasional occurrence of strong random noise signals, probably from the circuits, was annoying. It was found undesirable to operate the two units independently and simultaneously, because their keying circuits were not synchronized. This just meant that the two units had to be operated with the same keying interval, the 67-kc unit keying the system.

The A-scope was more useful than the facsimile recorder for immediate recognition for two reasons. A single echo provided a much greater contrast on the A-scope than the corresponding indication on only one line on the recorder, and discrimination between targets was easier with the A-scope. Echoes which were undoubtedly from mines were generally of very short duration, having very steep leading and trailing edges, as contrasted with echoes from rocks and other objects.

A typical mine echo, observed on a single sweep of the A-scope, is shown in Figure 19. Reverberation limited the useful range to ranges exceeding 50 feet. This is consistent with the theoretical dependence of the volume reverberation on distance; its intensity should go inversely as the square of the distance. Random noise signals would appear on the screen, especially when the recorder was not operating properly but since they usually did not last for more than one sweep, or, if repeated, appeared at different ranges on successive sweeps, they could be rejected. The operators soon became proficient in distinguishing sharp echoes, which could be attributed to mine-size objects, from generally diffuse echoes due presumably to other objects.

4.3 Frequency.

A valid comparison of the two frequencies used cannot be made because of the different directivity patterns (see Figures 5 through 8). Since most of the contacts were made at 100 kc, the least that can be said is that such a frequency is useful; however, 100 kc was used much more often than 67 kc, because the 100-kc transducer had a wider beam and could be trained. When the frequencies are comparable, detection appears to be influenced more by the beam width than by the frequency. More detailed tests of their relative merits would have to be done on the basis of comparable directivities.

Since the attenuation coefficient at 67 kc is about one-half that at 100 kc, the lower frequency should be advantageous in detecting objects at the longer ranges; at either frequency the wave length is small compared with the dimensions of a mine.

4.4 Beam width.

Observations with the 8° beam width (at 100 kc) indicated that it was considerably more valuable than the 2° beam width. In a few instances the 2° beam width was used in search for mines, but it had little or no success; on the other hand, with the 8° beam width an echo could generally be retained for five or six consecutive pulses with the boat underway. If the beam width is reduced by a factor of four, the number of consecutive echoes from the same target at the same speed would probably reduce to one or two, which is scarcely enough to reveal the existence of a target.

Tests with triplanes showed that the 8° beam width gave a more distinct and consistently stronger echo on both the A-scope and the facsimile recorder than the 2° beam width. This is illustrated in Figure 14, which shows a section of the recording paper when the beam width was changed from 8° to 2°. The effect of the increased reverberation with the 8° beam width was negligible.

The fact that objects on the bottom were detected at both short and long ranges indicates that the vertical beam width was suitable. However, the narrow vertical width (36° at 3 db down) of the 67-kc unit may account partially for the inferior results at this frequency.

4.5 Pulse length.

Preliminary tests indicated that a pulse length of 1 ms generally gave a more positive indication of a target (see Figure 15) than the shorter pulse lengths, and that the probable benefits associated with the shorter pulse lengths did not warrant extensive tests on the effect of pulse length, especially in view of the time available. Therefore, a pulse length of 1 ms was adopted for the operations, although it seems wise to retain a choice of pulse length in the equipment.

The effect of changing the pulse length from 0.25 to 1.0 ms is illustrated in Figure 15, which is a portion of the facsimile record. There is a noticeable though not objectionable increase in the reverberation with the 1.0-ms pulse length.

4.6 Tilt angle.

The tilt of the 100-kc transducer was varied in operations with the triplanes. These operations were started with the tilt at $+15^{\circ}$, the tilt angle being measured positively above the horizontal. Under these conditions the triplanes were detected at a depth of 30 feet, but not at a depth of 100 feet. The tilt was changed to -5°, which then enabled detection of the triplanes on the bottom. It was left at -5° for the rest of the summer's operations, since it was not convenient to adjust the tilt angle frequently during a run.

4.7 Thermal conditions.

Bathythermograph observations were taken on several days during operations. The gradients encountered ranged between 0.06° F/ft to 0.12° F/ft; about half the time isothermal layers were present to depths of from 25 to 45 feet.

The average range of contacts on a typical day varied between 200 and 300 feet; on one particular day when the average range was exceptionally large (370 feet), the gradient was fairly constant and small, about 0.06° F/ft. Since other conditions varied so much from day to day, further conclusions on the effect of thermal conditions cannot be drawn from the summer's operations.

4.8 Motion of the boat.

Two somewhat independent factors control the motion of the boat: the sea and the ability (or predisposition) of the coxswain to maintain a given heading. For a given heading the pitch and the roll are primarily controlled by the sea. The coxswain cannot control the motion of the boat and maintain the heading at the same time. It is, therefore, obvious that a boat of very stable design is desirable.

The stability of the 42-foot retriver left much to be desired. The effect of heavy seas on its motion was such that it was usually impractical, if not impossible, to follow a fixed course (at low speed), in sea state greater than 2, which would allow anything but a haphazard search of any particular area.

The yaw of a boat can be controlled to a much greater degree than is usual in ordinary operations. However, the average coxswain does not realize how much manipulation of the wheel is necessary. Ordinary handling of such a boat as the retriever usually allows much greater yaw than is tolerable in the present operations.

5. Operational Results

5.1 Types of search pattern.

The search patterns used comprised either straight or circular runs past the target areas (see also Section 3). Straight runs past targets were used from August 4 to 18; the circular pattern was then adopted in an effort to reduce the time to locate an object.

5.2 Number of contacts.

During the period from July 30 to September 15 a total of 313 sonar contacts was recorded. The actual time in the operating area during this period is estimated to be 36 hours, which results in an average of about 8 contacts per hour. Since some of this time was spent in maneuvering the boat at the end of each run, where no contacts could be expected, and in preparing to begin another run, the rate at which contacts appeared when expected was much greater.

These contacts were of varying degrees of validity; half (156) of the contacts was recorded during the first seven working days (through August 18), while the other half (157) was made in the final eighteen working days. During the early use of the equipment, lack of operating experience probably resulted in more frequent reports of doubtful contacts; also, in the areas where the initial searches were made there was a greater concentration of targets (including portions of a Wrecked plane which were strewn over a wide area) than in areas searched later.

Of the 313 sonar contacts, 158 were made at known boat positions, and have been analyzed quantitatively.

A total of sixteen mines and spheres were located on the bottom in the general area searched. The positions of the spheres are accurately known, as sights were taken on them from shore triangulation stations when they were put down, while the positions of the mines were known from either splash points or recovery points. The positions of mines known only on the basis of splash information are, of course, less reliable, as such positions are known to have been up to 100 feet from the actual recovery point.

5.3 Classification of contacts.

A preliminary analysis of the sonar contact data was made daily by plotting the positions of the underwater objects (splash points or recovery points) on charts of the area, together with the positions of the retriever at each contact. From the boat positions vectors were drawn corresponding to the range and bearing of the sonar contacts. The end of each one of these vectors represented the position of the sonar contact. Table II lists measurements of the distance from the ends of each of these vectors to the nearest splash or recovery position of a known object. The observed slant ranges were plotted directly, as the correction to horizontal ranges proved to be of the order of magnitude of the probable error in the reading of the range scale; for instance, if the observed slant range were 250 feet and the depth 50 feet, the horizontal range would be 245 feet.

Table II also gives (a) the distribution of these contacts according to the recorder data, classified as either <u>record observed</u> or <u>no record observed</u> or <u>recorder not operating</u>; and (b) the distribution of the contacts according to the sonar frequency at which each was made.

On 20 August a number of contacts was made in one particular area, which were especially interesting because of the complex echo which characterized some of them. They were in the vicinity of the supposed location of a mine, so divers went down and found the remains of a wrecked wooden ship of considerable age. A photograph of the A-scope displaying one of these echoes is given in Figure 17. The approximate location of the shipwreck is shown in Figure 23.

Examination of these charts might have indicated that the contacts would merely confirm the existence of an object

Table II

Intervals of range to nearest object	Contacts within range interval	Record observed	No record observed	Recorder not operating	Frequency	
					67	100
0 - 50 feet	21	9	3	9	11	10
51 - 100 feet	23	6	11	6	7	16
101 - 150 feet	22	6	6	10	6	16
Greater than 150 feet	82	---	---	----	19	63
Contacts on shipwreck (not counted above)	10	0	0	10	0	10

on the bottom somewhere in the vicinity of a splash point. However, the splash position is usually different from the bottom position, and the purpose of the sonar is to detect the bottom position. Its ability to do this was demonstrated on one instance during the operation of September 3; on that date a mine was dropped, and shortly thereafter the sonar retriever was guided around the splash point with the aid of radar. Several coincident circles were made without a contact, until the course was altered under the initiative of the sonar operator so as to bring the boat about 100 feet south of the area already covered. Echoes were immediately picked up from an object (which later proved to be the mine) at a position near the edge of the circle being traversed previously. Unfortunately, the 800-foot range setting was not being used on this occasion, as it was assumed that the boat was at all times within 400 feet of the mine; had the 800-foot range been used, the operation might have been completed earlier.

Table II shows that 66 contacts were within 150 feet of a known object, or 40% of a total of 148 (10 contacts which were presumably on the shipwreck have been subtracted from the original 158), while 14% lie within 50 feet of a known object. This means that 60% of the reported contacts were indicated at distances greater than 150 feet from any known underwater object, and therefore could not reliably be associated with a known target. It was felt that this apparently high proportion of false contacts might be due to the actual presence of unidentified targets at the positions of these contacts, and to the difference between splash points and bottom positions.

Another analysis was therefore attempted, in terms of the distribution of <u>groups</u> of contacts; this time the possible errors in positioning both the boat relative to shore and the contact relative to the boat were considered.

5.4 Classification of groups of contacts.

The 158 contacts were all plotted again, on a single chart, for convenience in visualizing them all together. Sections of this plot are shown in Figures 21, 22, 23, and 24. The symbols used thereon have these meanings: circles, splash positions; triangles, recovery positions; an arrow through a triangle denotes the direction in which the nose of the mine was pointed. Many of the contacts could be grouped together, the groups then being associated with nearby targets. Therefore, it seemed desirable to group these contacts within circles of fixed radius, the centers of the circles being correlated with known target positions. It was convenient to list in this report each group (according to the number of contacts within the circle of fixed radius) with the corresponding nearest known object and the distance to that object.

The contacts within each group do not coincide with each other because, <u>inter alia</u>, of unavoidable errors in locating their positions. Errors from several sources are added to the errors inherent in the sonar itself. For instance, in a few cases only splash positions for the mines were known; in others, positions of the recovered mines were subject to surveying errors. However, it is assumed here that all the error is in locating the contact on the chart, i.e., in locating the contact relative to the boat and the boat relative to shore.

Sights by the surveyors had to taken without warning, while the boat was in motion, and a slight delay always occurred between recognition of the echo and notification of the surveyors by radio; the average error is estimated at 0.05° in bearing, or about five feet in the actual position of the boat (assumed at a range of 1800 yards from the surveying station). The error in determining the absolute bearing of the contact, from the boat's compass and from the relative bearing scale on the sonar, was estimated at 5°, leading to an error of about 30 feet in the relative position of a contact at a range of 300 feet. The error in reading the range scale, and the finite beam width of the transducer, lead to an uncertainty of about 10 feet, while a correction for the slant range and unknown systematic errors (such as in plotting) might be assumed to amount to a total additional uncertainty of 15 feet. In view of the nature of these errors, it seems justifiable to add them algebraically and account for them simply by a total uncertainty of 60 feet. Therefore, it was assumed that the true position of a plotted contact might lie anywhere within 60 feet of that point.* Undoubtedly, there are valid contact points at distances greater than 60 feet from known targets, but due to errors greater than those mentioned above they do not coincide with the true positions.

The groups analyzed here consisted of points lying within circles 60 feet in radius. Since most of the known targets which were sought lay outside these circles, the number of groups lying at distances greater than 150 feet from mines or spheres is also listed, this distance representing an upper limit to the total possible error which would be expected.

Table III contains the following information: (1) groups classified according to the number of contacts lying within circles 60 feet in radius; (2) total number of such groups; (3) total number of contacts in such groups; and (4) number of such groups at distances greater than 150 feet from known mines or spheres and which might be interpreted as indicating an unidentified underwater object.

* Of course, the most probable positions of the contact lie within an area which is not necessarily a circle. For convenience a circle of sufficient radius (60 feet) to include the probable positions was chosen.

Table III

Number of Contacts occurring in group	Number of such groups	Total number of contacts	Groups at distances greater than 150 ft. from mines or spheres
1	32	32	23
2	26	52	12
3	7	21	3
4	2	8	2
5	6	30	4
6	1	6	0
7	0	0	--
8	0	0	--
9	1	9	0
Total	75	158	44

Among the 36 groups of two or more contacts, totalling 98 contacts (excluding those near the shipwreck and the airplane debris), there are 21 groups (63 contacts) lying within 150 feet of a known object, or 60% of the total number of groups, which may be compared to the 40% of all contacts within 150 feet of a known object (Table II).

The number of groups lying within 50 feet of a known object is five (17 contacts) or 14% of the 36 groups, which may be compared to the 14% of all contacts within 50 feet of a known object (Table II).

In Table IV are listed all the known underwater objects with the corresponding nearby groups and the distances from the center of the group to the object, and the estimated number of times the objects were passed within sonar range during the summer's operations.

Table IV

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Object	No.*	No. of Passes	No. of Contacts in Nearby Group	Distance to Object From Center of Nearby Group	No. of Nearby Groups d ≤ 60ft.	60ft. < d ≤ 150ft.	d > [illegible]
Mk 36 Mine	27	2	3	200	0	0	[illegible]
			2	180			
Mk 36 Mine	26 S	4	9	70	0	[illegible]	[illegible]
Mk 36 Mine	27 S		1	175			
			2	160			
Mk 36 Mine	28	12	5	250	2	0	1
			5	60			
			2	coincident			
Mk 36 Mine	29 [illegible]	8	5	coincident	1	4	0
				[illegible]			
				[illegible]			
				[illegible]			
			2	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	200	[illegible]	0	
				[illegible]			
				[illegible]			

[illegible]

Table IV (cont)

Object	No.	No. of Passes	No. of Contacts in Nearby Group	Distance to Object From Center of Nearby Group	No. of Nearby Groups $d \leq 60$ft.	60ft. $< d \leq 150$ ft.	$d > 150$ft.
Mk 36 Mine	31	6	2	220	0	1	2
			2	300			
			2	110			
38-in. sphere	32	7	6	coincident	1	3	1
			5	100			
			3	350			
			2	70			
			2	150			
38-in. sphere	33	4	3	75	0	1	0
38-in. sphere	34	4	2	100	0	1	0
38-in. sphere	35	4	2	50	1	0	0
Mk 36 Mine	42	2	2	370	0	0	1
			2	370			
Mk 36 Mine	43	8	2	600	1	0	1
			2	60			

Table IV (cont.)

Object	No.	No. of Passes	No. of Contacts in Nearby Group	Distance to Object From Center of Nearby Group	No. of Nearby Groups $d \leq 60$ft.	No. of Nearby Groups 60ft. $< d \leq 150$ft.	No. of Nearby Groups $d > 150$ft.
Mk 36 Mine	44	4	2	140	0	1	0
Mk 25 Mine	45	4	2	170	1	0	2
			2	60			
			2	200			
Mk 39 Mine	49	3	3	80	0	1	1
			2	300			
Shipwreck			5	-			
			3	-			
Aircraft debris			5	-			
			5	-			
			4	-			
			4	-			
			2	-			

Distribution of the isolated contacts

Less than 60 feet from mine or spheres:	3 contacts
60 to 150 feet from mines or spheres:	6 contacts
Greater than 150 feet from mines or spheres:	23 contacts

6. Conclusions

6.1 General Conclusions.

1. Detection and location of bottom mines with the Type 1174 Sonar is feasible over the design range of 800 feet.

2. The effectiveness of the equipment in the type of operation described in this report is apparently limited more by errors in the plotted contact information than by errors due to the equipment itself. The uncertainties in knowing the position of the boat and the absolute bearing of a contact are the largest sources of error.

3. Effective use of the gear in a boat such as a torpedo retriever is seriously limited by seas greater than sea state 2.

4. It is possible with the equipment to distiguish a type of echo possessing extensive structure, which could be associated with known rock formations in the area, from the sharp and narrow echo characteristic of mines.

5. A system combining a small-boat sonar with radar-guided navigation is particularly appropriate when the approximate locations of mines are known. Such a system not only allows the radar operator efficiently to direct the boat near the target, but also allows him immediately to check the consistency of the contacts.

6.2 Specific Conclusions.

1. Both of the frequencies used were found to be suitable for mine detection, but a valid comparison of the two was not practical because of different directivity characteristics of the two units.

2. It was found that the widest horizontal beam available in the present equipment should be used when under way in searching for mine-like objects.

3. A sonar system lacking a training device for the transducers is severely limited in its use.

4. A permanent record is an invaluable adjunct to the information presented on a cathode ray oscilloscope in a sonar system.

7. Recommendations

7.1 General.

1. While the adequacy of the equipment has been established, further tests not only of its parameters but also of the equipment itself as a part of a system are highly desirable.

2. It is recommended that the use of a stabilized mounting to reduce the effects of roll, pitch, and yaw be investigated.

3. A system employing small-boat sonar demands able and experienced personnel, not only for sonar operation but particularly for handling the boat.

4. Investigation should be made of the possibility of methods or devices which would enable the boat's position to be known on board and on shore without individually manned shore stations. Precise navigation is indispensable.

5. In further tests it is recommended that the different frequencies be operable under the same conditions of beam width and trainability.

7. Specific.

1. There should be available in both units a horizontal beam width of at least 8°, since the increased reverberation and decreased resolution with the wider beam seem to be off-set in practice by the greater probability of getting a contact. A choice of narrower beams may be included for use when conditions warrant.

2. The facsimile recorder should be replaced by one of improved mechanical and electrical design.

3. A training system should be incorporated into the 67-kc unit, and training motors having a greater range of speed should be used.

4. An accurate compass and a compass repeater should be incorporated in order to make the absolute bearing of the transducer immediately available to the sonar operator.

5. The control of the entire equipment should be arranged to be easily operable by one person.

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R.E. Barrett

G.W. Landwehr
G.W. Landwehr

J.K. Major
J.K. Major

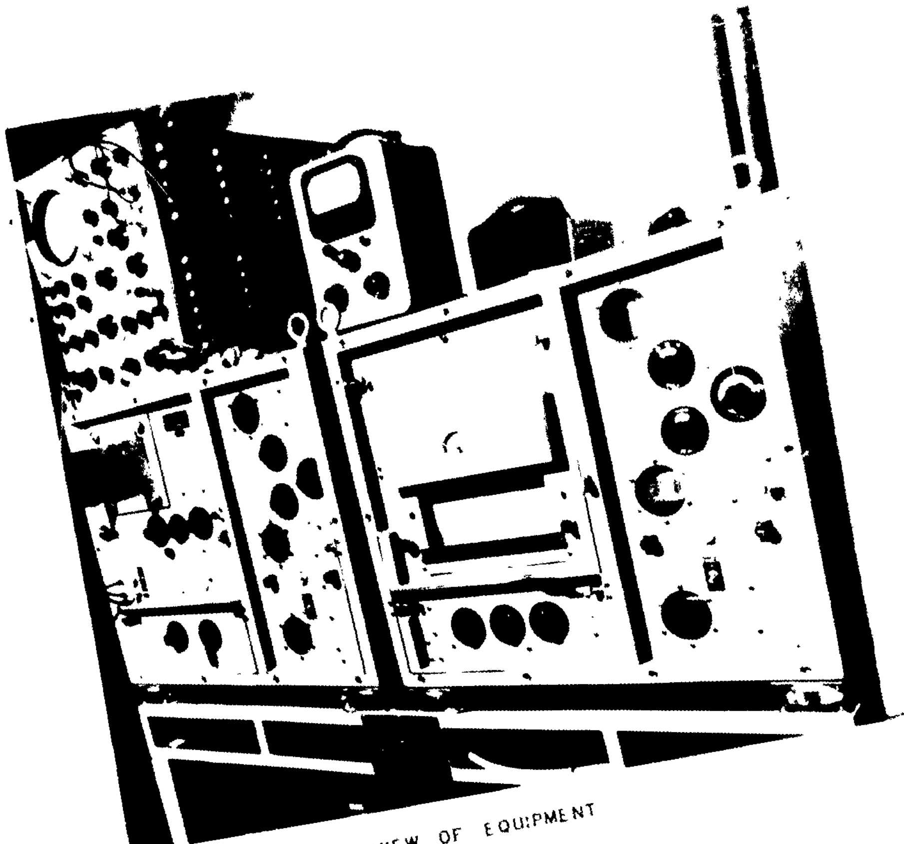

FIG 1 VIEW OF EQUIPMENT

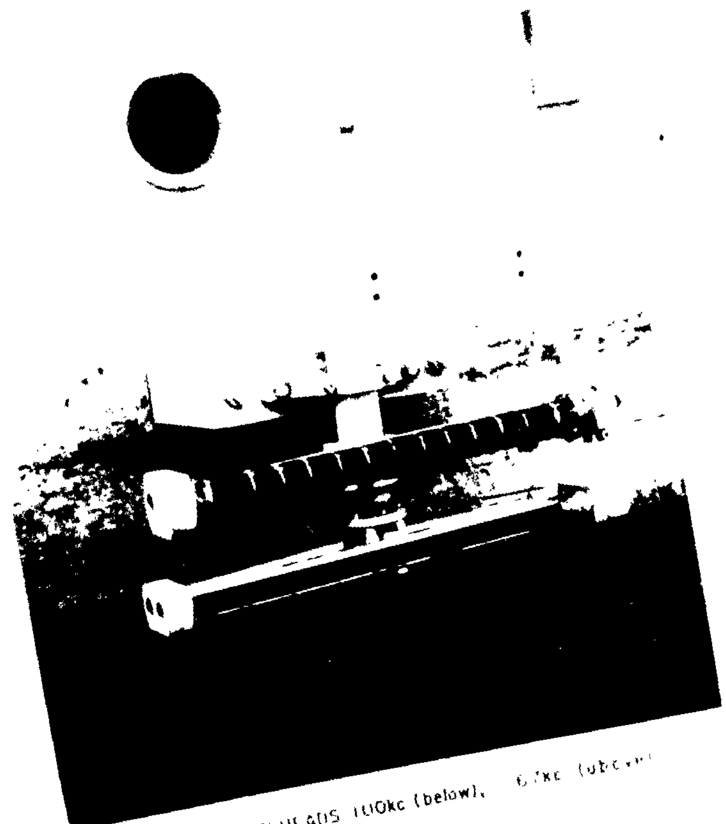

FIG 2 TRANSDUCER HEADS 100kc (below), 6?kc (above)

FIG. 3 VIEW OF CABIN AND REAR EXTENSION OF THE RETRIEVER

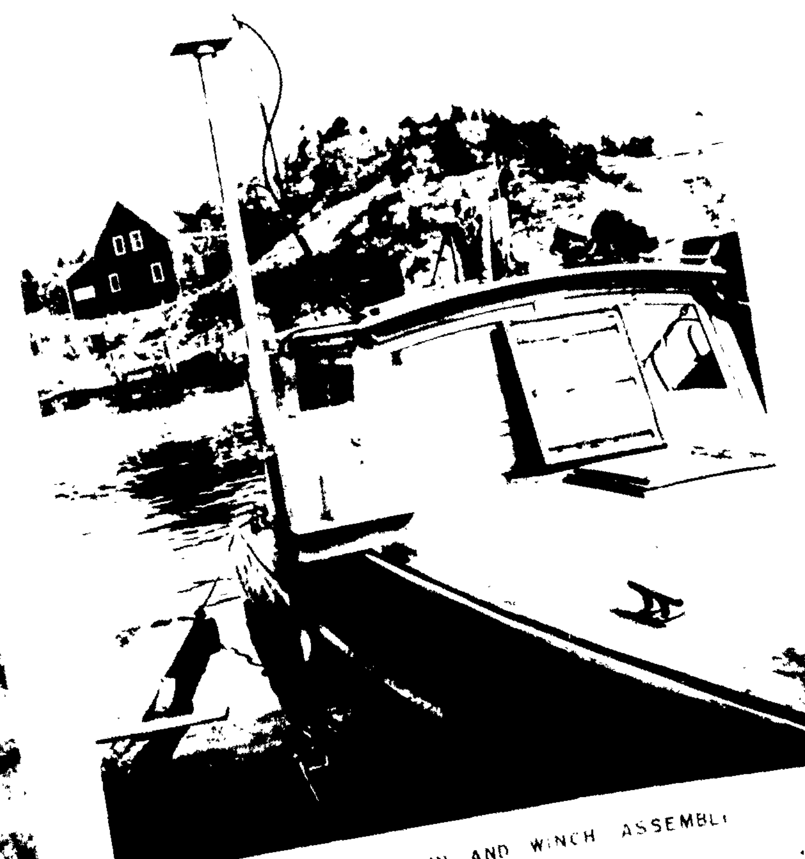

FIG 4 TRANSDUCER COLUMN AND WINCH ASSEMBLY

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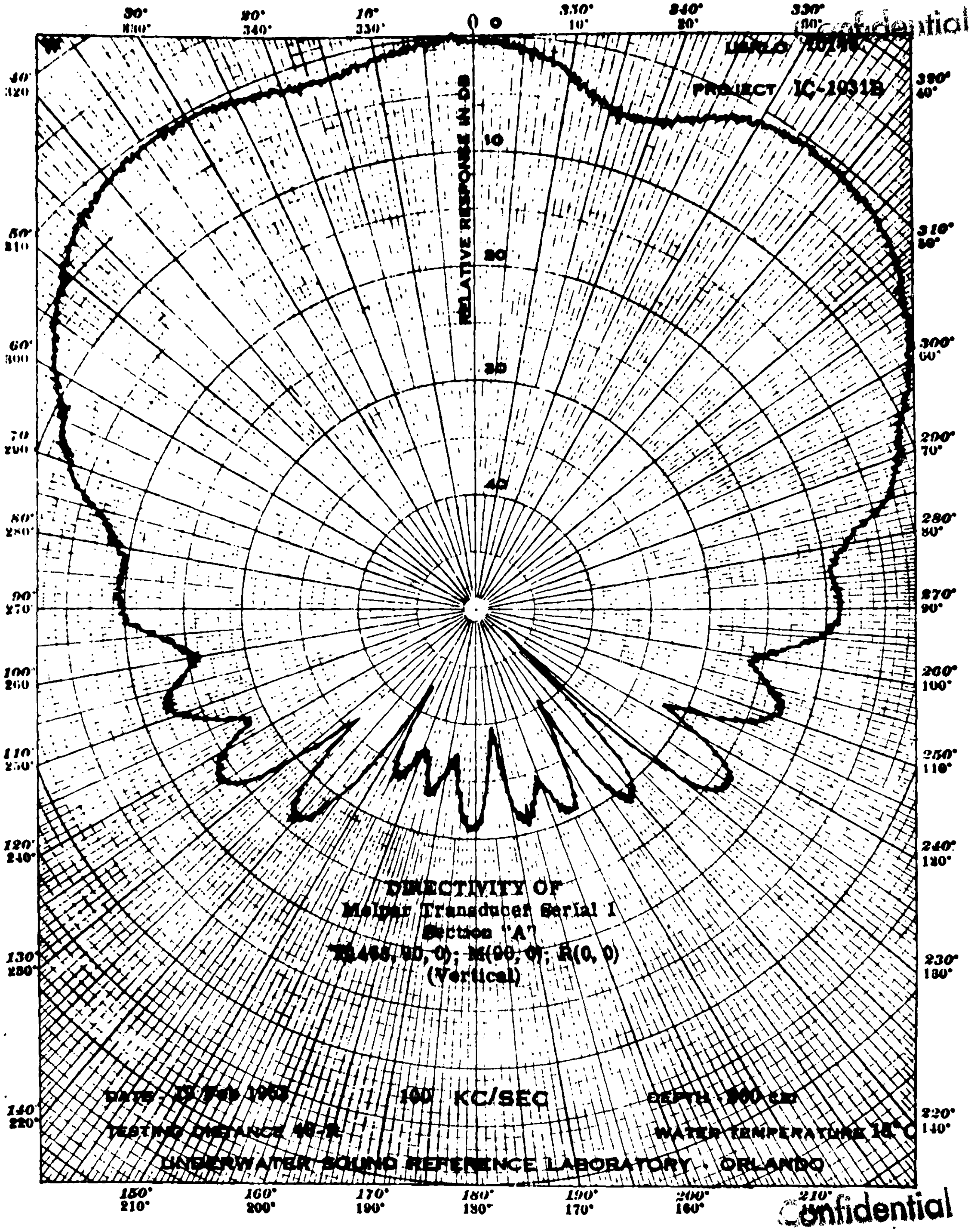

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FIG. 5 100kc VERTICAL BEAM PATTERN

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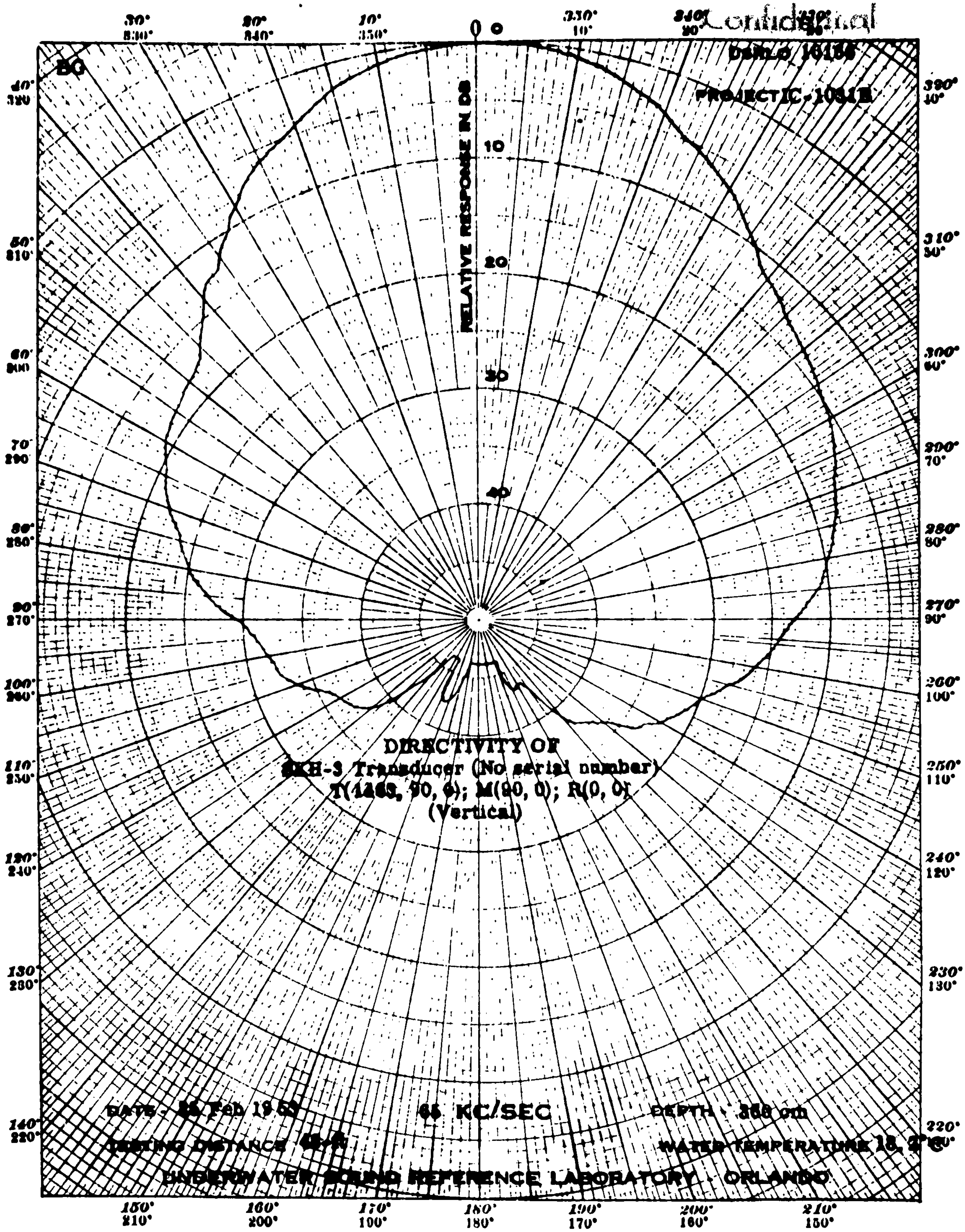

FIG. 6 67kc VERTICAL BEAM PATTERN

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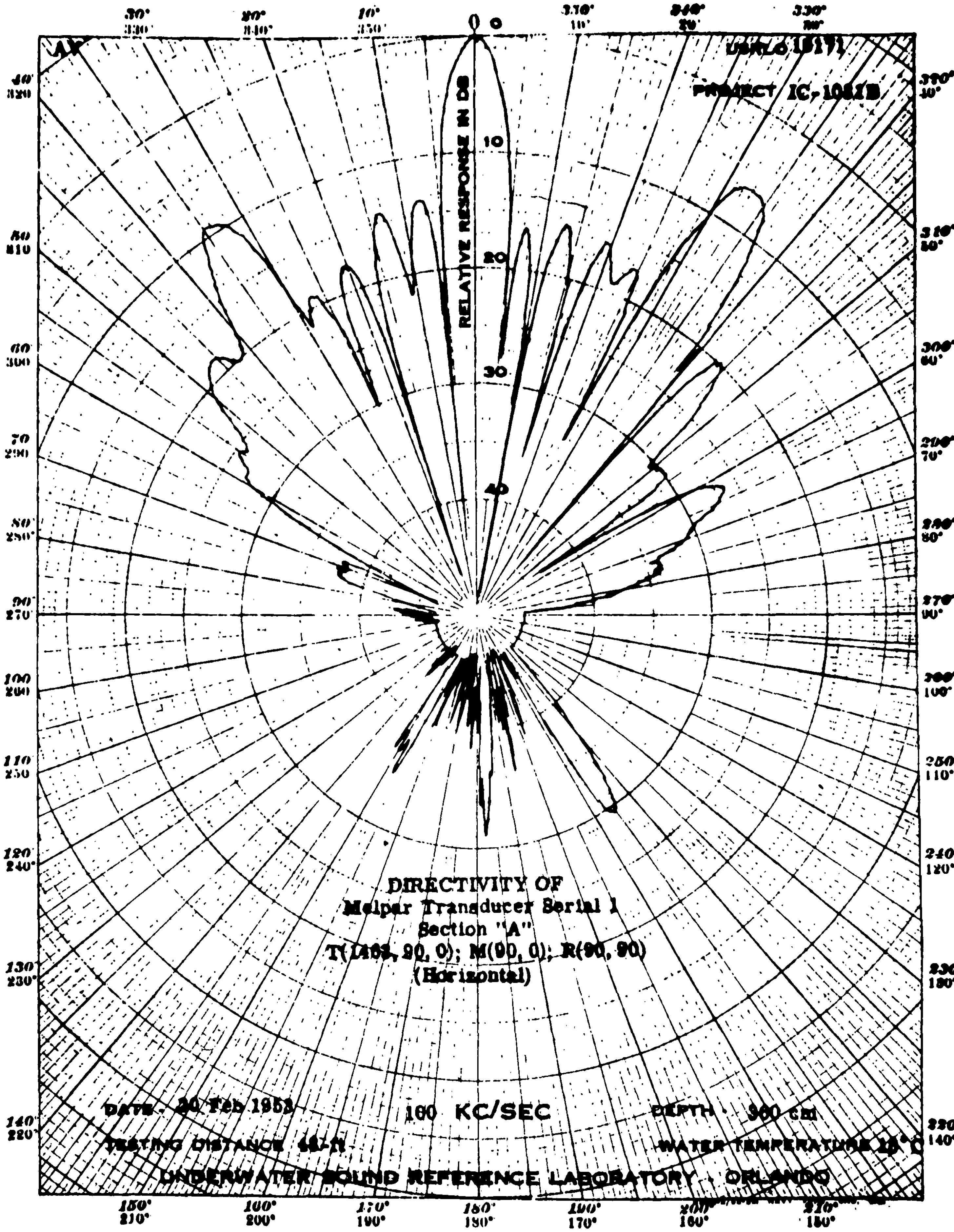

FIG. 7 100kc HORIZONTAL BEAM PATTERN

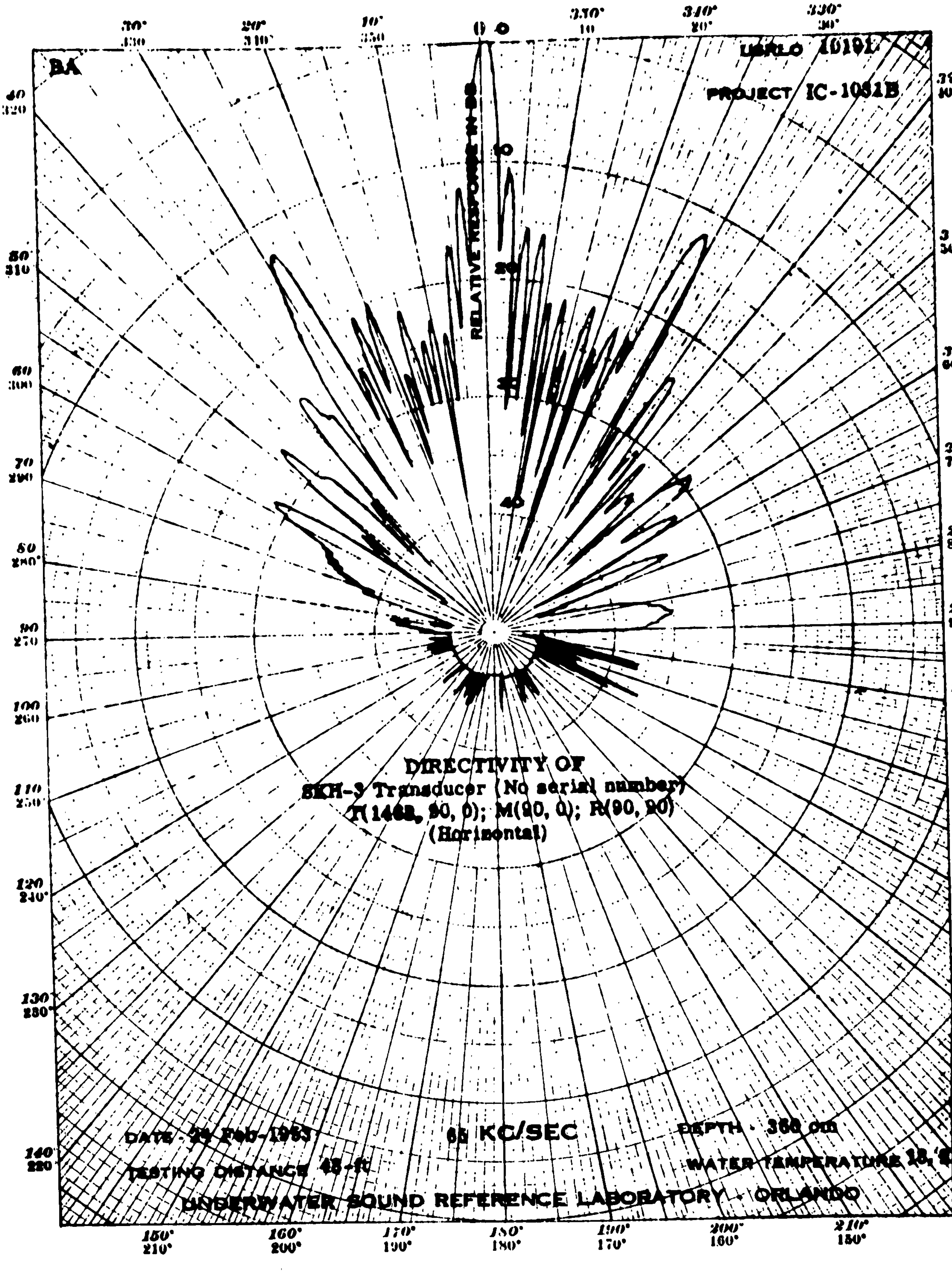

FIG. 8 67kc HORIZONTAL BEAM PATTERN

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FIG.9 THE TRIPLANE TARGET

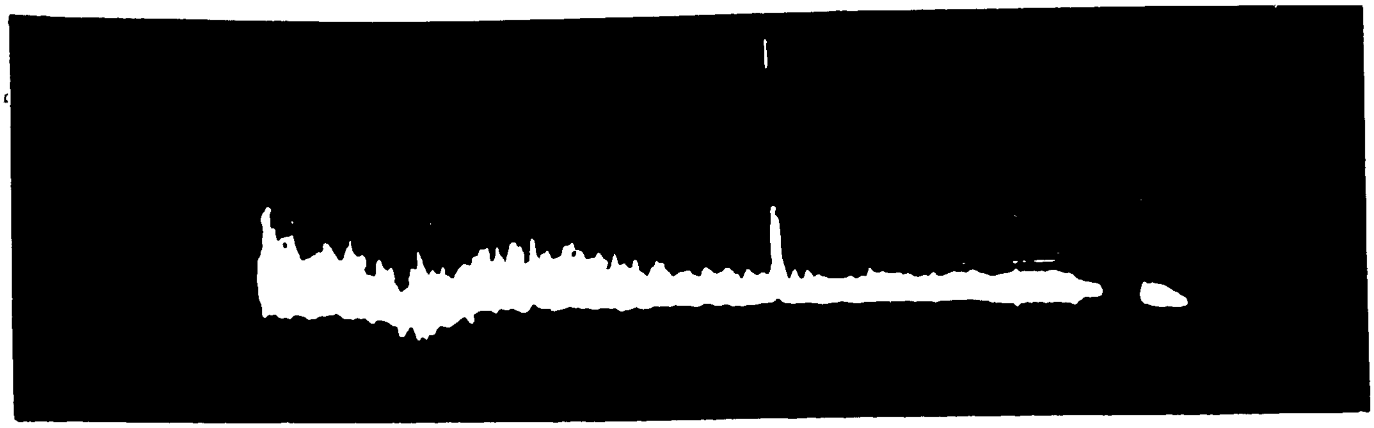

FIG. 10 OSCILLOGRAM OF TRIPLANE ECHO AT 100kc, 0.25MS

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FIG. 11 RECORDER ECHO PATTERN OF FLOATING CAN BUOY & TRIPLANE AT 40 FEET DEPTH. —100Kc, 1.0MS.

FIG.12 TYPICAL TRIPLANE ECHO - 100kc 1.CMS. 0°

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FIG. 13 ECHO FROM FLOATING CAN BUOY – 87kc. 0.25MS, 2°

2°

8°

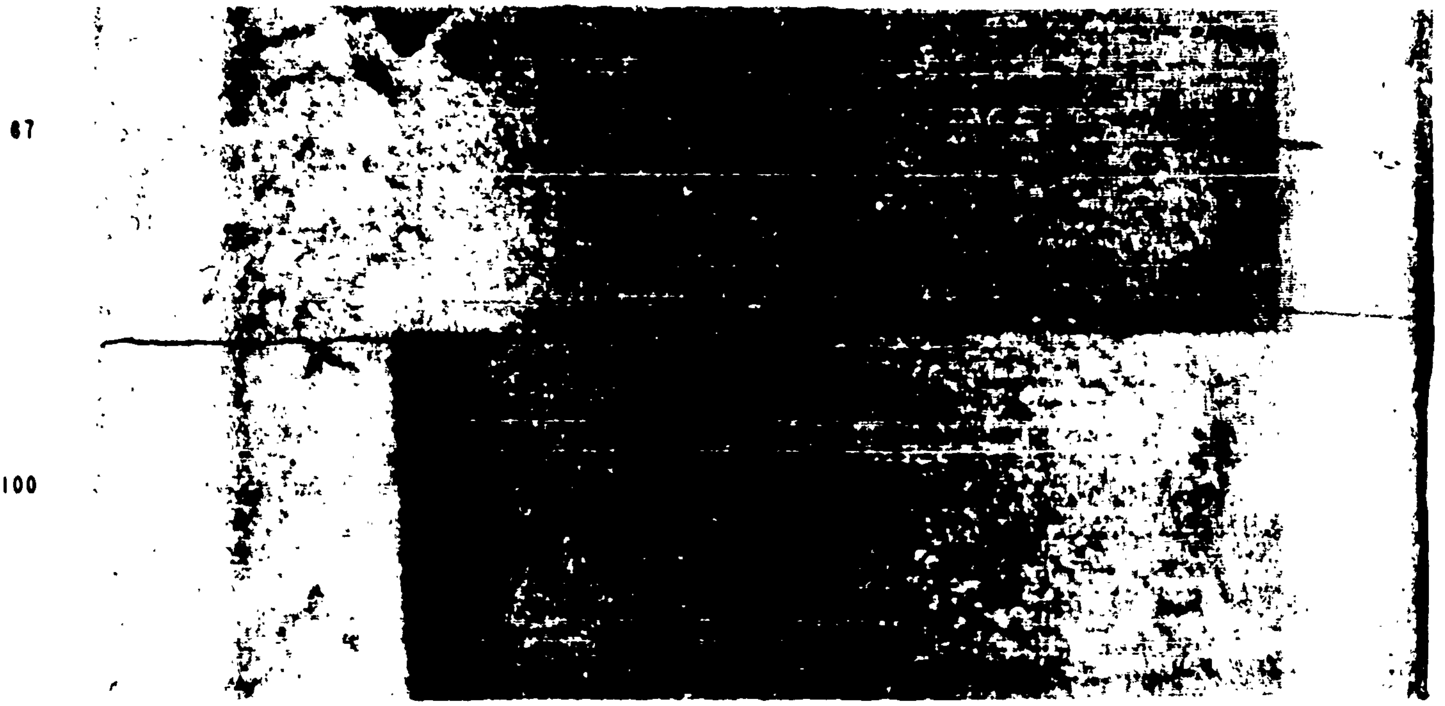
FIG. 14 CHANGE FROM 8° TO 2° HORIZONTAL BEAM WIDTH, RUBBER COATED TRIPLANE. 100kc, .25MS

1.0

0.25

FIG. 15 CHANGE FROM .25 TO 1.0MS PULSE LENGTH, RUBBER COATED TRIPLANE—100kc, 8°

43-FOOT DEPTH



72-FOOT DEPTH

113-FOOT DEPTH

FIG.16 REVERBERATION PATTERNS AT VARIOUS DEPTHS — 100kc. AT 25MS 2°; 67Kc. AT .25MS 2°

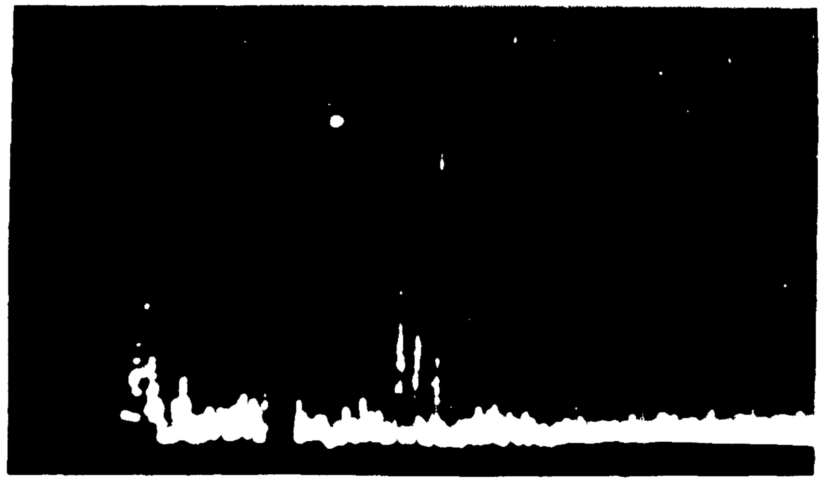


FIG. 17 OSCILLOGRAM OF ECHO FROM SHIPWRECK AT 100Kc, 1.0MS

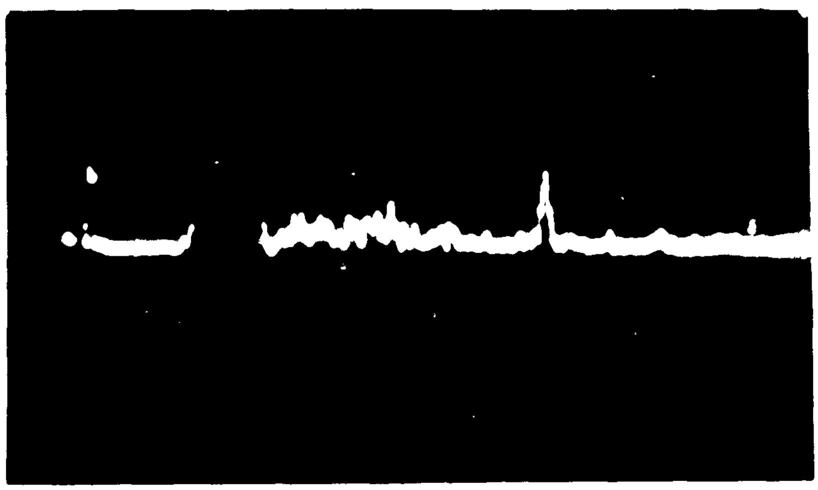


FIG. 18 OSCILLOGRAM OF ECHO FROM SPHERE AT 100Kc 1.0 MS

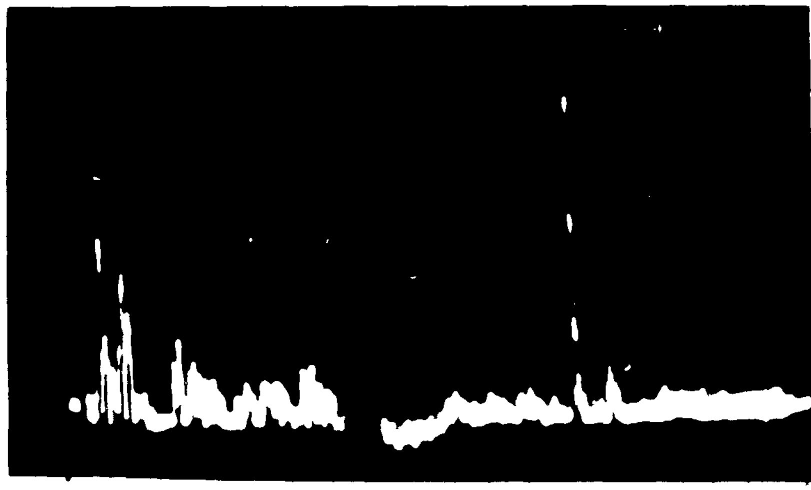


FIG. 19 TYPICAL ECHO FROM MINE (MK 36) AT 100Kc, 1·0MS.

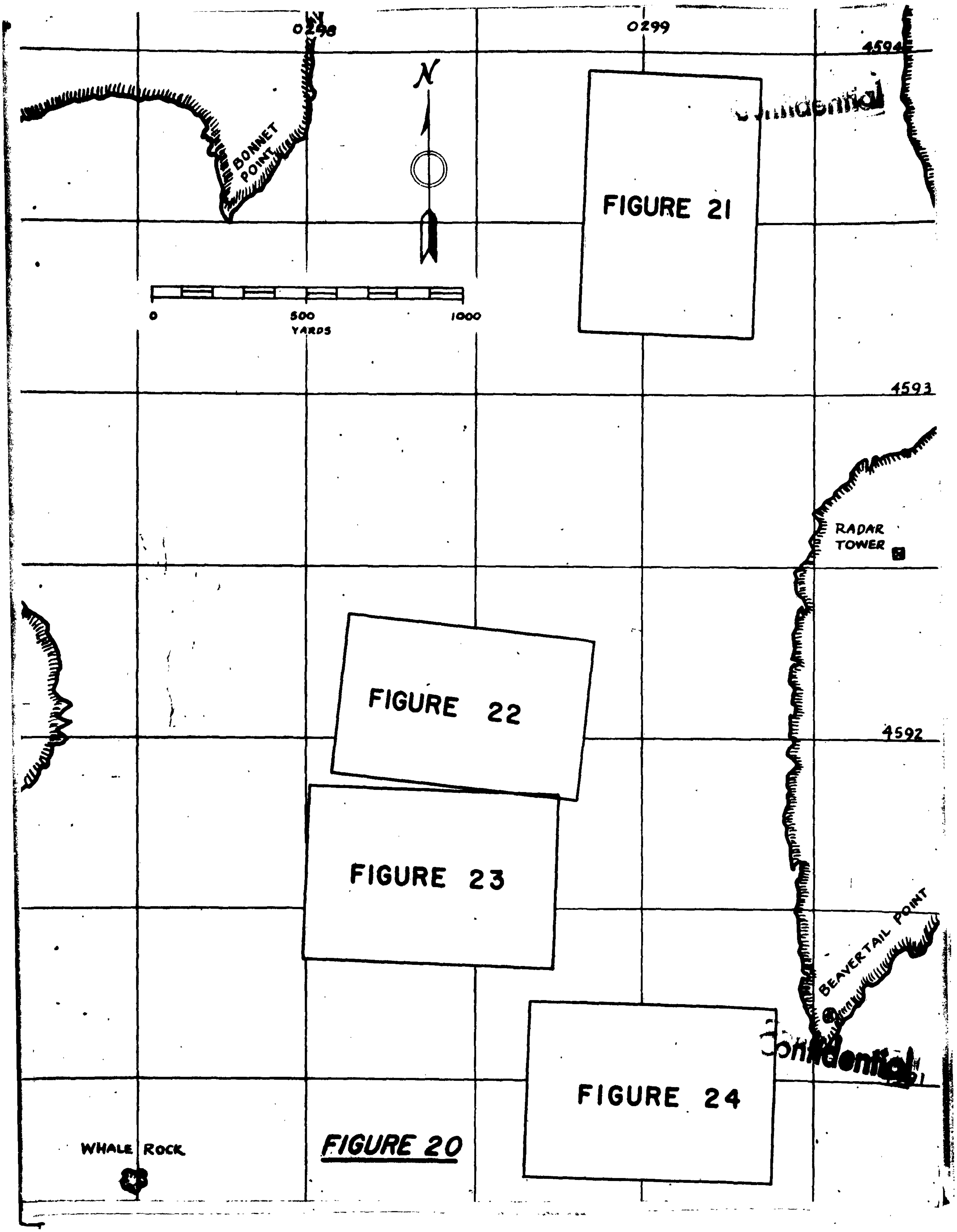

0298
0299
4594
4593
4592
N
0
500
1000
YARDS
BONNET POINT
FIGURE 21
Confidential
RADAR TOWER
FIGURE 22
FIGURE 23
BEAVERTAIL POINT
Confidential
FIGURE 24
WHALE ROCK

FIGURE 20

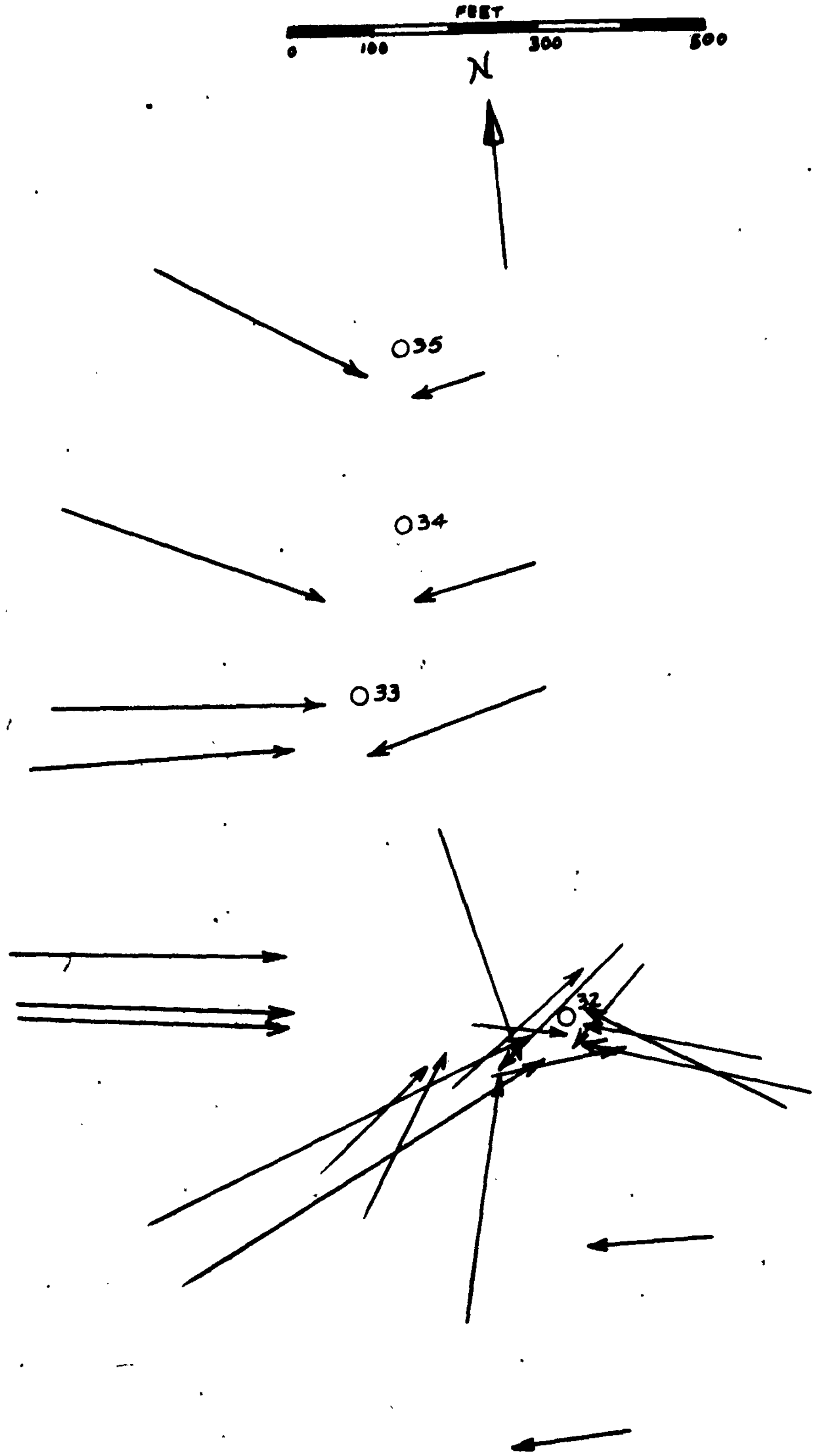
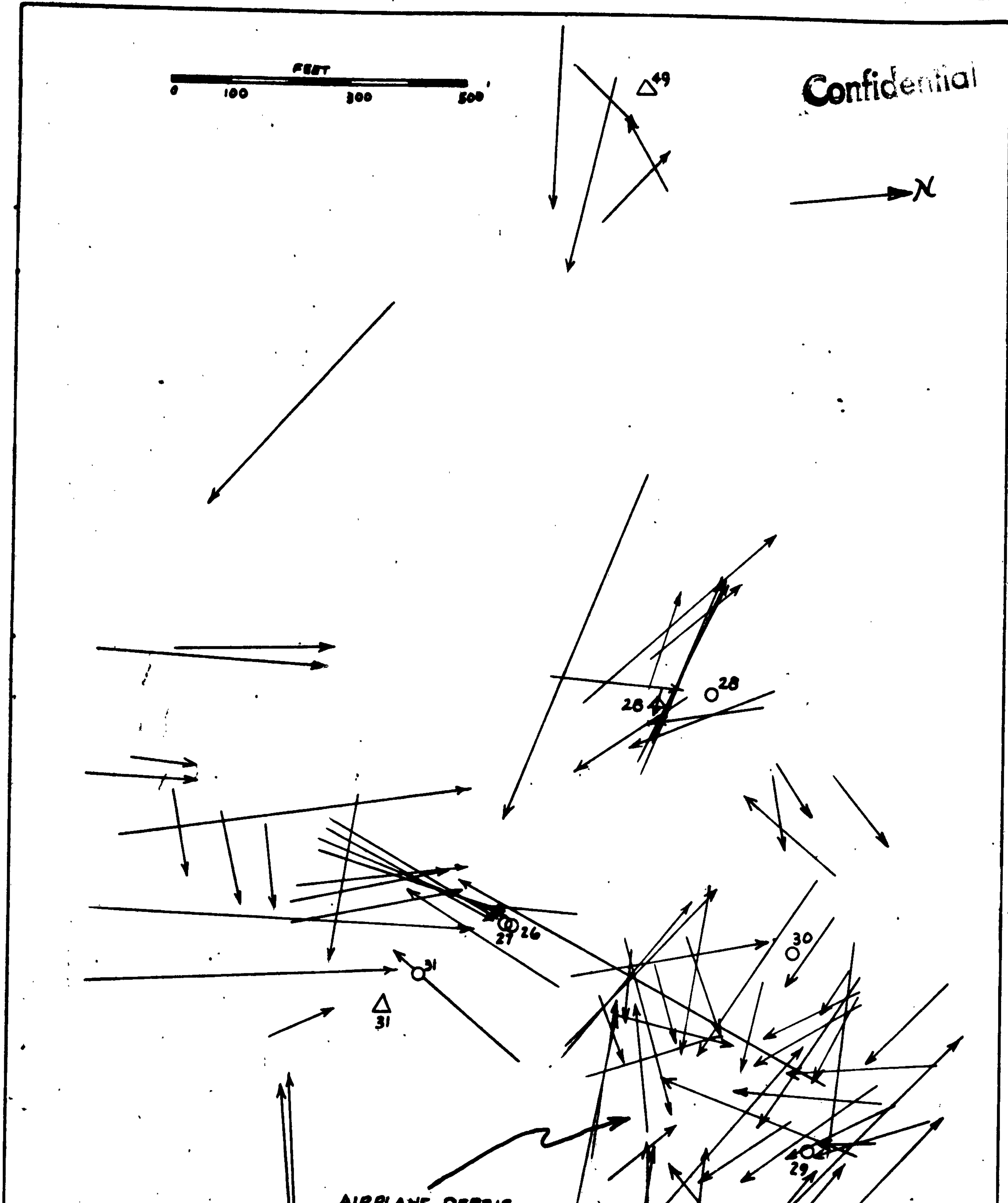


FIG. 21



FEET
0
100
300
500'
49
Confidential
N
28
28
26
27
30
31
31
29
AIRPLANE DEBRIS
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FIG. 22

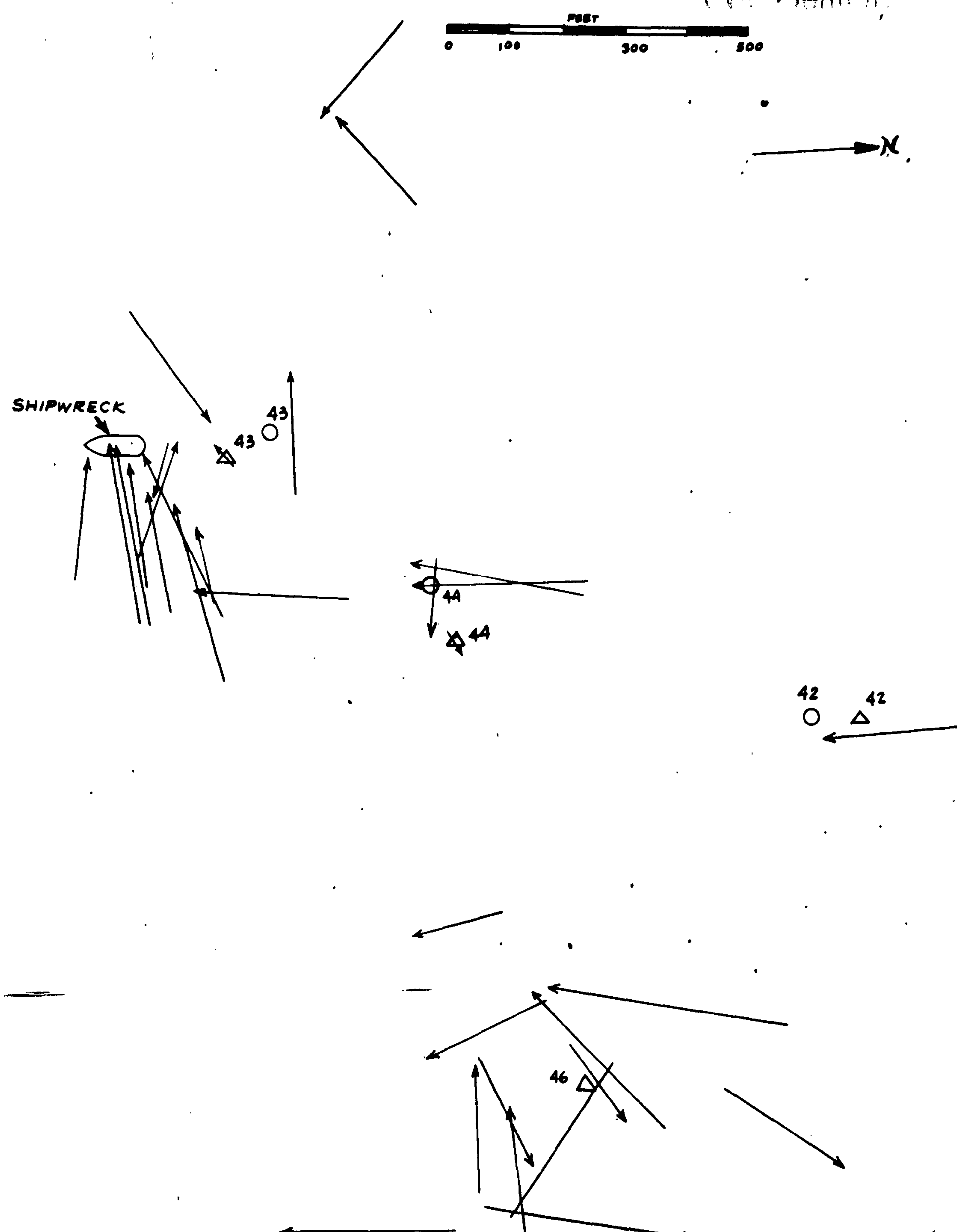

FIG. 23

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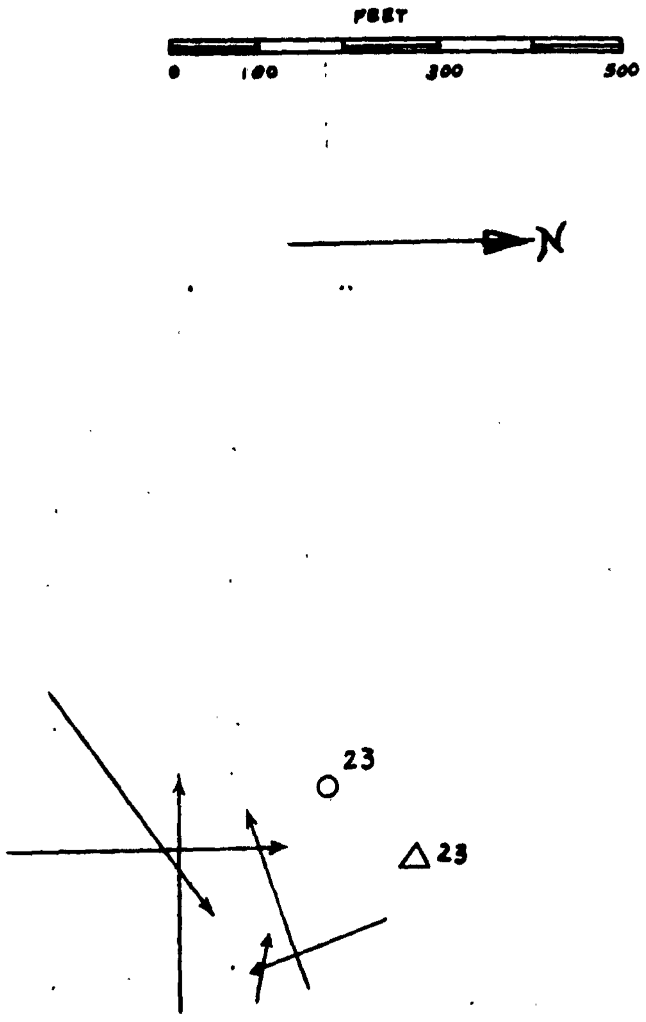

O = SPLASH POINT

△ = RECOVERY POINT

FIG. 24